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Estimate of the Impact of Noise From Jet Aircraft Air Carrier Operations

Bolt Beranek and Newman, Inc.
Cambridge, MA

Prepared for

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Prepared For:

U.S. Environmental Protection Agency
Office of Noise Abatement and Control

Under Contract No. EPA 68-01-5014

This report has been approved for general availability. The contents of this report reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policy of EPA. This report does not constitute a standard, specification, or regulation.

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16. ABSTRACT

This report contains an update and revision of the estimated noise impact of airport jet air carrier operations in the years 1975 and 2000. These estimates are based on the current takeoff flight procedures, the 1979 FAA fleet forecast, and current definitions of new technology aircraft. They do not assume additional regulatory actions, either in aircraft noise certification or in airport operations, nor do they assume additional noise control efforts on the part of individual airports.

These results are based largely on the methodology and data contained in a prior study [1], except for updating certain basic information in that study from 1975 to 1979 and revising a part of the methodology for estimating population impacted.

The sensitivity of the results with respect to changes in these four factors has been investigated with a simplified noise characteristic vs. area impact model. The model directly relates the noise characteristic, L_{dn}, calculated at a 1000-ft slant distance, for each of the four busy runway average airport fleets to the area contained within each L_{dn} contour, as calculated in Ref. 1. The model was calibrated for current standard takeoff procedures using three cases from the Ref. 1 study which covered the range of results from maximum to minimum impact. The model enables evaluation of the variation of both noise and operations parameters, but not takeoff flight procedures, over a much wider range of alternatives than those considered in this report.

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SUMMARY

This report contains an update and revision of the estimated noise impact of airport jet air carrier operations in the years 1975 and 2000. These estimates are based on the current takeoff flight procedures, the 1979 FAA fleet forecast, and current definitions of new technology aircraft. They do not assume additional regulatory actions, either in aircraft noise certification or in airport operations, nor do they assume additional noise control efforts on the part of individual airports.

These results are based largely on the methodology and data contained in a prior study [1], except for updating certain basic information in that study from 1975 to 1979 and revising a part of the methodology for estimating population impacted.

The results are summarized in Table 1, together with a comparison with those of Ref. 1. They indicate that the total area, including airport and other compatible areas within L_{dn} contours of 65, 70, and 75 dB may be expected in the year 2000 to be approximately 44, 46 and 43%, respectively, of that estimated for the year 1975. They also indicate that the population in the year 2000 may be expected to be about 36% of the 1975 values within the L_{dn} 65 dB contour, 34% of the 1975 values within the 70 dB contour, and 18% of the 1975 values within the L_{dn} 75 dB contour. Although these year 2000 percentages imply significant reductions in aircraft/airport noise impact, the absolute number of people estimated to remain impacted by noise is not insignificant; i.e., 1,742,000 within L_{dn} 65 dB, 447,000 within L_{dn} 70 dB, and 68,000 within L_{dn} 75 dB.

TABLE 1 COMPARISON OF ORIGINAL[1] AND REVISED ESTIMATES OF AREA AND POPULATION FOR THE YEARS 1975 AND 2000 FOR EXPECTED FLEET GROWTH, STAGE 3 CERTIFICATION AND THE FAA AC91-39 TAKEOFF PROCEDURE (CASE 1, 1, 1) AS A FUNCTION OF L_{dn}.

QUANTITY	SOURCE	L_{dn} > 65			L_{dn} > 70			L_{dn} > 75		
		1975	2000	%[2]	1975	2000	%	1975	2000	%
AREA[3] (In sq.mi.)	Ref. 1	2169	1304	60	807	605	75	310	179	58
	Revised[4]	2169	957	44	807	368	46	310	134	43
	Δ	0	347		0	238		0	45	
POPULATION (In thousands)	Ref. 1	6174	3581	58	1620	1033	64	393	125	32
	Revised[4]	4889	1742	36	1313	447	34	384	68	18
	Δ	1285	1839		307	586		9	57	

Notes [1] Original estimates from Ref. 1.

[2] % is value in year 2000 relative to value in 1975.

[3] Area is total contour area including airport and other compatible areas as well as residential area.

[4] Combination of all changes as shown in Tables 13 and 14.

1. INTRODUCTION

A prior study [1] forecast the noise exposure of civil air carrier airplanes through the year 2000. The study investigated the effects of a range of alternatives for aircraft certification for noise, for aircraft operation during takeoff, and for two rates of fleet growth. Results of calculations of population and land area impact were presented for each of these alternatives for six study years between 1975 and 2000.

The primary bases for this comprehensive study were the fleet forecasts and operations activity data available in the 1975 base period. Since that time, several significant developments have occurred that affect the future forecasts of air carrier operations. Among these are:

- Definition of the "future technology" aircraft of the 1980s;
- Permission for development of a new class of commuter airline turboprop aircraft seating up to 60 passengers; and
- Deregulation of airlines, which permits easy access to most important markets and abandonment by large air carriers of many small markets to commuter airlines and air taxis.

These developments have significantly altered the future air carrier jet aircraft fleet forecast and have enabled more exact definition of its noise characteristics. This study has been undertaken to apply this new information to the estimation of the future impact of airport/aircraft noise, assuming that no new certification or flight operation procedures are introduced in the intervening period.

The basic methodology used in Ref. 1 is outlined in Fig. 1. This study necessarily retains all of the methodology and operations data bases, with the following four exceptions:

- Revision of the estimation of population in Airport Category B,
- Update of the fleet forecast from 1975 to 1979 FAA forecast,
- Constraint on growth of air carrier operations at Category C-1 airports, LaGuardia and Washington National, and
- Update of noise levels to include defined new technology aircraft: A-300, B757, B767, and DC9-80.

The sensitivity of the results with respect to changes in these four factors has been investigated with a simplified noise characteristic vs. area impact model. The model directly relates the noise characteristic, L_{dn}, calculated at a 1000-ft slant distance, for each of the four busy runway average airport fleets to the area contained within each L_{dn} contour, as calculated in Ref. 1. The model was calibrated for current standard takeoff procedures using three cases from the Ref. 1 study which covered the range of results from maximum to minimum impact. The model enables evaluation of the variation of both noise and operations parameters, but not takeoff flight procedures, over a much wider range of alternatives than those considered in this report.

This report contains a discussion of the four updates and/or revisions to the Ref. 1 study assumptions, the development of the noise characteristic vs. area impact model, and an analysis of the sensitivity of the 1975 baseline and the year 2000 impact area and population results to these updates and/or revisions.

1) Define 4 Airport Categories: (For airports with more than 20 jet operations per year in 1975).

A: 13 Major International Airports that could have SST aircraft

B: 113 Airports with 4-engine aircraft

C-1: 2 Airports (LaGuardia and National) with no 4-engine aircraft but high impact

C-2: 179 Airports with only 2- and 3-engine aircraft.

2) For each airport category and operating procedure:

2.1 Define a single busy runway, flight tracks, utilizations, and stage lengths for both takeoffs and landings (at each runway end) based on a sample of airports.

2.2 Define average daily effective operations based on 1975 operations at all airports in category and on 1975 day-night ratios of sample airports.

2.3 Define average daily effective operations on each busy runway by applying busy runway utilizations determined from sample airports to 2.2 above.

2.4 Using FAA's Integrated Noise Model (modified version) and EPNL data by aircraft type, calculate area vs L_{dn} at 5 dB intervals for busy runway operations.

2.5 Scale areas in 2.4 to total area for nation by accounting for actual operations at each airport in category.

2.6 Determine population impacted from prior relationships between population and area within contours for each average airport (average = total ÷ number of airports in category) then multiply average airport populations by number of airports in category.

3) Projections for Future Years:

3.1 Define number of aircraft in fleet by aircraft type for future years (e.g., moderate growth was based on Ref. 2) and determine allocation amongst the 3 FAR Part 36 Stages.

3.2 Define number of operations by aircraft type and by stage using 1975 data on number of operations by aircraft type times number of aircraft of that type forecast for the future year fleet.

3.3 Compute operations for each airport category by aircraft type and by stage by multiplying the operations in 3.2 by the proportion of aircraft operations by aircraft type in each airport category in 1975.

3.4 Compute area and population for each year using basic procedures of 2.2 through 2.6 above.

FIG. 1 SIMPLIFIED SUMMARY OF AVPORT MODEL FOR ESTIMATING AREA AND POPULATION IMPACTS. (See Ref. 1 for additional detail.)

2. DESCRIPTION OF UPDATES AND REVISIONS

This section describes the basis for the updates and revisions to the original study [1] in each of the following areas:

- Population of Airport Category B
- Fleet forecast
- Constraint on future operations in Airport Category C-1
- Noise data for new technology aircraft.

(a) Population of Airport Category B

The original study contains relationships between the total contour area for an average airport in each category and its associated population. These relationships are illustrated in Fig. 2. The data for AVport A (13 airports) and C-1 (2 airports) were obtained from a complete set of airport contours and their associated populations. Thus, for these two airport categories, the total population equals the number of airports per category times the population in the average airport, with the latter uniquely related to the total contour area for the average airport with the functions shown in Fig. 2. These relationships may be expected to be valid for modeling purposes as long as there is no change at one or more airports in the area-population relationship (such as might occur with a change of flight tracks away from populated areas to over ocean), and all other changes in fleet mix and growth affect all airports in the category equally, such that the ratio of contour areas between any one airport in the category and the average airport remains constant.

The curve for Category C-1 is revised for this report, as shown in Fig. 2. The revision is based on the original data in

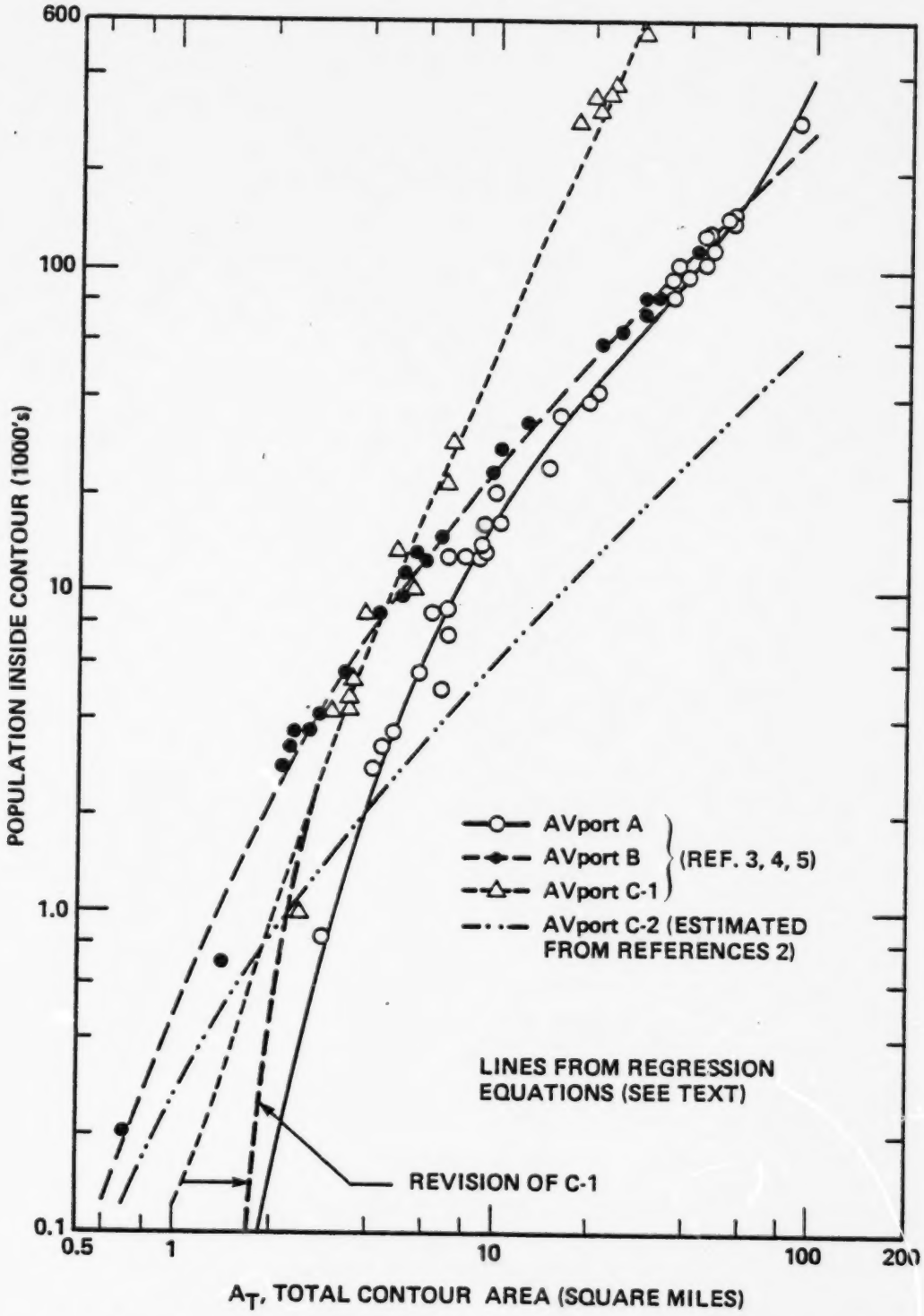

FIG. 2 COMPARISON OF DATA RELATING POPULATION AND TOTAL CONTOUR AREA FOR AVPORTS WITH REGRESSION FUNCTIONS USED FOR ANALYSIS WITH REVISION FOR CATEGORY C-1 FOR AREAS LESS THAN APPROXIMATELY 2.5 SQ. MILES. (FROM REF. 1 WITH REVISION OF C-1.)

Ref. 3, which showed that the population approaches zero for average areas less than 1.5 square miles, and is consistent with the lowest triangular data point on the figure.

The relationship for Category B is based on the data for 11 airports that were obtained in the 23-airport study [3]. These 11 airports were originally selected as part of a sample of the top 20 probably most highly impacted airports in the country. Thus, they tend to be adjacent to centers of large populations with the attendant high volume of operations, and are also located so that a significant part of the population is overflown and exposed to noise.

These data for the 11 airports were utilized in Ref. 1 for the calculation of population for all of the 113 airports in Category B. However, the population density around the majority of the Category B airports was much less than that around the 11 airports. The magnitude of this difference may be seen in Table 2, by comparing the population density in annular rings around airport centers for three subdivisions of Category B, i.e., B-1, B-2, and B-3. Category B-1 consists of the set of 11 airports for which a set of population vs contour areas was available and is represented by the curve for AVport B in Fig. 2. Category B-2 consists of the next largest 30 airports in Category B, i.e., those with over 100 jet aircraft operations per day in 1975. Category B-3 consists of the remaining 72 airports in Category B that had less than 100 jet aircraft operations per day in 1975. The population density for Category B-2 within 10 miles of the airport is on the average approximately 46% of that of Category B-1. The population density for Category B-3 within five miles of the airport is on the average approximately 22% of that of Category B-1. It is significant to note that categories with a higher volume of

TABLE 2 COMPARISON OF 1970 CENSUS POPULATION DENSITY BY AIRPORT CATEGORY IN RADIAL RINGS AROUND CENTERS OF AIRPORTS[1]

AIRPORT CATEGORY	NUMBER OF AIRPORTS	RING OUTER RADIUS IN STATUTE MILES									
		1	2	3	4	5	6	7	8	9	10
A[2]	13	987	1942	2925	3311	3570	3888	3558	3448	3134	3188
B-1[2]	11	493	2651	4360	4471	3888	3446	2881	2522	2579	2409
B-2[2]	30	201	1432	1790	1847	1699	1766	1629	1188	1165	907
B-3[3]	72	134	867	745	781	629	639	539	492	399	361
C-1[2]	2	477	11877	16783	22750	21631	18142	16601	13444	8847	7547
C-2[4]	179	395	841	864	759	692	599	481	428	342	292

Notes [1] Data from FAA Environmental Data Base, 1970 Census.

[2] Based on complete sample.

[3] Based on sample of 65 out of 72 airports.

[4] Based on sample of 131 out of 179 airports.

daily operations often have a higher population density. Thus, within category B, there is a tendency for airports with more noise due to number of operations also to have more people to be affected per operation, compounding the impact.

Table 3 summarizes the equations for the population-area curves in Fig. 2. These equations are taken directly from Ref. 1, except for the modifications required to model the new subcategories B-2 and B-3. These equations are well defined for the region of the curves in Fig. 2 that contain data, but are not well defined outside of these regions. The subdivision of the areas in category B amongst the subcategories was based on the number of operations at the airports in each subcategory and the scaling procedure of Ref. 1.

(b) Update of Fleet Forecast

The prior study contained a moderate and an expansive growth rate for the civil air carrier jet aircraft fleet. The moderate growth rate was based on FAA estimates in 1975 [6]. The FAA 1979 expected forecast [7,8] has a significantly lower growth rate than the 1975 forecast.

A comparison of these two forecasts is given in Table 4. The major difference appears to be in the narrow-body two-engine category, which in 1975 was forecast to be much larger than currently forecast. Part of this difference may be attributed to the opening up of the commuter airline service through deregulation and the concurrent advent of new quiet turboprop aircraft in the 30-seat range, some of which may be expected to grow to 60 seats. It is anticipated that these new commuter aircraft may displace jet aircraft at many of the smaller airports in future years.

Other differences may result from factors such as the rising cost of fuel as a major operating constraint, the corresponding

TABLE 3. SUMMARY OF POPULATION EQUATIONS USED IN MODEL.[1]

Airport Category	Area as a % of Total Category	No. of Airports	Constants			
			a_0	a_1	a_2	a_3
A[2]	100	13	-2.560	6.975	-4.140	0.9726
B[3]: B-1	26	11	-0.3313	2.494	-0.9767	0.2099
B-2	46	30	-0.6685	2.494	-0.9767	0.2099
B-3	28	72	-0.9696	2.494	-0.9767	0.2099
C-1[2][4]	100	2	-0.9224	3.279	-0.7978	0.2127
C-2[2]	100	179	-0.5997	2.063	-0.9654	0.2822

Note:

[1]Population for average airport (1000s) $= 10^{(a_0 + a_1x + a_2x^2 + a_3x^3)}$

where $x = \log_{10}$(average airport area in sq.mis.) and average airport area is total area in category divided by number of airports in category.

[2]Unchanged from Ref. 1.

[3]Constant for a_0 for B-1 category is unchanged from Ref. 1, but is changed in B-2 and B-3 to reflect lower population densities.

[4]For average airport areas less than 3 square miles the revised C-1 curve is used in this report rather than the equation.

TABLE 4 COMPARISON OF 1975 AND 1979 AIR CARRIER FLEET FORECASTS FOR EXPECTED GROWTH (Based on References 6, 7 and 8)

AIRCRAFT TYPE	Forecast Year	YEAR					
		1975	1980	1985	1990	1995	2000
Wide Body, 4 engine (B747)	1975	96	130	200	270	445	620
	1979		140	254	334	425	575
Wide Body, 3 engine (DC-10, L1011, B777)	1975(1)	204	264	421	588	888	1188
	1979		230	440	645	793	908
Wide Body, 2 engine (A-300, B767)	1975(2)	0	0	367	518	782	958
	1979		32	135	339	547	772
Narrow Body, 4 engine (DC8, B707)	1975	622	454	98	0	0	0
	1979(3)		349	112	81	50	33
Narrow Body, 3 engine B 727	1975	790	881	799	715	342	334
	1979		948	876	831	658	435
Narrow Body, 2 engine (DC9/10-50, B737 DC9-80, B757)	1975	528	766	1049	1315	1645	1975
	1979		611	805	730	694	652
TOTAL	1975	2240	2495	2934	3406	4102	5075
	1979	-	2310	2622	2960	3167	3375

Note 1) Shown as 2/3 engine in Ref. 1, but numbers came from FAA forecast on 3-engine DC 10, L1011 aircraft.

2) Category did not exist in Ref. 1, but is used here for the 1975 FAA forecast new technology aircraft, shown in Ref. 1 as a 3 engine narrow body new technology aircraft.

3) Narrow body aircraft after 1985 presumed to be re-engined to stage III rule.

desire to increase load factors, the higher efficiency in terms of direct operating cost for the new larger aircraft and longer stage lengths. There are small internal inconsistencies with the 1979 forecast: e.g., the steady phaseout of the narrow-body four-engine aircraft from 1985 to 2000, rather than a constant number between at least 1985 and 1995, representing those 50 or more aircraft that are reengined in the early 1980's.

For the purposes of this study, the fleet has been assigned to FAR Part 36 noise stage compliance (Stage 1, 2, or 3 replaces the "noncomply," "1969," and "1975" rule terminology of Ref. 1). The results are summarized in Table 5, and the rules used for the assignment are noted below the table. These assignment rules are similar to those of Ref. 1 but are adjusted to fit the updated forecast and expected entry dates of new aircraft.

The average daily number of operations for the fleet was computed by using the aircraft productivity factors (number of operations per aircraft) of Ref. 1. These factors were based on the actual number of operations performed in 1975 and the number of aircraft in the fleet inventory in that year. The only apparent distortion caused by using the number of aircraft in inventory rather than the number of active aircraft appears to be in the narrow-body four-engine category where only about 515 of the 622 were apparently in actual service. However, this discrepancy is probably consistent through 1980 and becomes immaterial after 1985 when all but a few of these aircraft will be retired and the remainder are reengined.

Table 6 summarizes the 1979 forecast in terms of average daily operations, and Table 7 compares the 1979 and 1975 [1] operations forecasts. The 1975 forecast shows almost 80% more

TABLE 5. 1979 FLEET FORECAST INCLUDING ESTIMATED ALLOCATION OF AIRCRAFT AMONG FAR-36 STAGES 1, 2, AND 3.

AIRCRAFT TYPE	FAR Part 36 Noise Stage	Year					
		1975	1980	1985	1990	1995	2000
Wide Body, 4 engine[1] (B-747)	1	45	45	0	0	0	0
	2	51	95	254	334	425	575
	Total	96	140	254	334	425	575
Wide Body, 3 engine[2] (DC10, L1011, B777)	2	204	230	440	593	642	642
	3	0	0	0	52	151	266
	Total	204	230	440	645	793	908
Wide Body, 2 engine[3] (A-300, B767)	3	0	32	135	339	547	772
	Total	0	32	135	339	547	772
Narrow Body, 4 engine[4] (DC8, B707)	1	622	349	0	0	0	0
	3	0	0	112	81	50	33
	Total	672	349	112	81	50	33
Narrow Body, 3 engine B727	1	572	572	0	0	0	0
	2	218	376	876	831	638	435
	Total	790	948	876	831	659	435
Narrow Body, 2 engine[5] (DC9/10/50, B737) (DC9-80, B757)	1	480	480	0	0	0	0
	2	48	131	611	530	400	222
	3	0	0	194	200	294	430
	Total	528	611	805	730	694	652
TOTAL		2240	2310	2622	2960	3167	3375

Note 1. Some will probably be produced to meet State 3 levels, a reduction of 1 dB for the EPNL at 1000 ft and max climb power; however, a new production rule would be required to assure this result.

2. Stage 3 aircraft phased in at rate of ½ new production in 1985-90. 2/3 new production in 1990-95 and all of new production in 1995-2000 with the remainder to Stage 2.

3. A-300 was certified as a Stage 2 aircraft and presumably its derivatives would not have to meet Stage 3, unless the rule is amended. However, its noise performance is essentially that of Stage 3 and the A-310 is to be certified to Stage 3.

4. The 112 and 81 aircraft shown re-engined in 1985 and 1990 are probably excessive and the correct number is probably nearer to 50-70; however, this discrepancy has no measurable effect on the noise model.

5. Existing aircraft were phased out of the fleet after 1985 in accordance with Ref. 1; aircraft added in 1975-1980 were Stage 2 and the remainder were Stage 3 aircraft.

TABLE 6. ANNUAL AVERAGE DAILY OPERATIONS BASED ON 1979 FLEET FORECAST USING PRODUCTIVITY FACTORS FROM REF. 1(1)

AIRCRAFT TYPE	FAR Part 36 Noise Stage	Year					
		1975	1980	1985	1990	1995	2000
Wide Body, 4 engine (B-747)	1	158	158	0	0	0	0
	2	180	335	894	1176	1496	2025
	Total	338	493	894	1176	1496	2025
Wide Body, 3 engine (DC10, L1011, B777)	2	1274	1436	2747	3702	4009	4009
	3	0	0	0	325	943	1661
	Total	1274	1436	2747	4027	4952	5670
Wide Body, 2 engine (A-300, B767)	3	0	358	1510	3792	6119	8636
	Total	0	358	1510	3792	6119	8636
Narrow Body, 4 engine (DC8, B707)	1	2919	1638	0	0	0	0
	3	0	0	526	380	235	155
	Total	2919	1638	526	380	235	155
Narrow Body, 3 engine (B727)	1	6398	6398	0	0	0	0
	2	2439	4206	9799	9296	7360	4866
	Total	8837	10604	9799	9296	7360	4866
Narrow Body, 2 engine (DC9/10/50, B737) (DC9-80, B757)	1	8442	8441	0	0	0	0
	2	844	2304	10745	9320	7095	3904
	3	0	0	3412	3517	5170	7562
	Total	9286	10745	14157	12837	12265	11466
TOTAL		22654	25274	29663	31508	32367	32818

Note 1. Productivity factor, i.e., number of annual operations for a single aircraft, were taken from Ref. 1 and applied to the same aircraft, except that the 2-engine wide body is assigned the factor for the 3-engine narrow body and the Stage 3 narrow body used in Ref. 1.

TABLE 7. COMPARISON OF ANNUAL AVERAGE DAILY OPERATIONS BASED ON 1979 FLEET FORECAST, TABLE 6, WITH OPERATIONS IN REF. 1 BASED ON 1975 FORECAST.

AIRCRAFT TYPE	Forecast	YEAR					
		1975	1980	1985	1990	1995	2000
Wide Body, 4 engine (B-747)	1975	338	458	704	951	1567	2183
	1979	338	493	894	1176	1496	2025
Wide Body, 3 engine (DC10, L1011, B777)	1975 (1)	1274	1649	2629	3672	5545	7419
	1979	1274	1436	2747	4027	4952	5670
Wide Body, 2 engine (A-300, B767)	1975 (2)	0	0	4105	5794	8948	10716
	1979	0	358	1510	3792	6119	8636
Narrow Body, 4 engine (DC8, B707)	1975	2919	2131	460	0	0	0
	1979	2919	1638	526	380	235	155
Narrow Body, 3 engine (B727)	1975 (3)	8837	9855	8938	7998	3826	3736
	1979	8837	10604	9799	9296	7360	4866
Narrow Body, 2 engine (DC9/10/50, B737) (DC9-80, B757)	1975	9286	13471	18449	23127	28930	34733
	1979	9286	10745	14157	12837	12265	11466
TOTAL	1975	22654	27564	35285	41542	48616	58787
	1979	22654	25274	29663	31508	32367	32818

Note 1. Shown as 2/3 engine in Ref. 1, but numbers came from 1975 FAA forecast for 3-engine DC-10 and L-1011.

2. Category did not exist in Ref. 1, but here is used for 1975 FAA forecast the new technology aircraft shown in Ref. 1 as a 3-engine narrow body new technology aircraft.

3. Includes 171 Stage 3 aircraft (1013 operations/day) which were allocated to the Stage 3, 2-engined narrow body category (B757 and DC9-80) for noise computations in year 2000.

operations (2.5 dB on an energy basis) than the 1979 forecast. For the most part, these operations result from the two-engine aircraft, which were more numerous in the 1975 fleet forecast, and also are assumed in this methodology to have more operations per aircraft.

(c) Capacity Limits for Airport Category C-1

One of the assumptions in the Ref. 1 study is that each airport would expand as required to meet the increased number of operations forecast. This probably is a valid assumption for most airports, but not for LaGuardia and Washington National, which are now essentially near capacity and which comprise Category C-1. The current FAA constrained estimates of air carrier traffic through 1990 show a *decrease* in air carrier operations from an annual average of 227,000 in 1980 to 197,000 in 1990. See Appendix A for additional details.

For the constrained cases, the number of air carrier jet aircraft daily operations at the average C-1 airport is 620 in 1980, 580 in 1985, and 538 in 1990, 1995, and 2000. It is presumed that increased passenger demand with decreased operations will lead to use of larger aircraft; e.g., the New York-Washington shuttle is planned to change to A-300 aircraft from 727 and DC-9 aircraft. However, the nature of this transition is not easy to forecast, especially to the year 2000. Therefore, the procedure was to allocate the full number of wide-body three-engine aircraft (DC-10 and L-1011) to the C-1 category (1.3% of the operations of this type), and to allocate the remainder in proportion to the remaining slots divided by the full number of operations otherwise to be allocated. An example of the effect of the constraint and this allocation method is contained in Table 8.

TABLE 8. EXAMPLE OF THE CHANGE IN FLEET MIX IN YEAR 2000 FOR AN AVERAGE AIRPORT IN AIRPORT CATEGORY C-1 AS A RESULT OF CONSTRAINING ITS TOTAL OPERATION.

Aircraft Type	Number of Daily Operations By Aircraft Type		
	Original	Constrained	Change
2/3 Engine wide body	48.2	48.2	0
3 Engine narrow body	138.2	55.9	-82.3
3 Engine narrow body (new technology)	396.5	160.2	-236.3
2 engine narrow body	677.3	273.7	-403.6
Total	1260.2	538.0	-722.2

(d) Updated Noise Levels for New Technology Aircraft

The original study investigated the potential effect of the application of several noise certification rules to the future noise impact. The rules included the 1975 FAA proposal (now Stage 3 as promulgated), and the 1980 and 1985 EPA proposed further reduction. The study utilized five basic types of aircraft and adjusted their baseline noise vs distance for various thrust levels as required to just meet each of the rules on takeoff and landing. The new technology aircraft was assumed to be a narrow-body three-engine aircraft, and its noise performance was derived from the 727 baseline noise. This procedure resulted in an aircraft that is noisier than the A-300, which is a new technology aircraft of about 1.75 times the weight of a 727.

For the current estimates, the new technology aircraft is defined as a wide-body two-engine aircraft (B-767 and A-300) with the noise characteristics derived for the B-767 in Ref. 9. Additionally, the Stage 3 narrow-body two-engine aircraft (B-757 and DC9-80) is defined with the noise characteristics derived for the DC9-80 in Ref. 9.

These updated estimates are compared in Table 9 to those of Ref. 1 for the FAA AC91-39 departure procedure. The only changes of significance are the substitution of 98 EPNdB (wide-body two-engine) for 103 EPNdB (Stage 3 narrow-body, two-engine) and 96 EPNL (Stage 3 narrow-body, two-engine) for 100.5 EPNdB. Both of these changes represent a reduction of approximately 5 EPNdB for the selected thrust condition and distance. Note that these updates only affect the noise level at a fixed distance for a given thrust condition: They do not account for noise decreases that might be anticipated on both takeoff and landing as a result of improved aircraft aerodynamics.

TABLE 9 COMPARISON OF NOISE LEVELS AT MAXIMUM CLIMB POWER AT 1000 FT SLANT DISTANCE

AIRCRAFT TYPE	FAR 36 Stage	NOISE LEVEL (EPNL)	
		Reference 1	Updated Estimate
Wide Body, 4 engine (B 747)	1	104	104
	2	104	104
	3	103	103
Wide Body, 3 engine DC-10, L1011, B777	2	101	101
	3	99.5	99.5
Wide Body, 2 engine (A-300, B767)	3	--	98 (1)
Narrow Body, 4-engine (DC-8, B707)	1	113	113
	3		99 (2)
Narrow Body, 3 engine (B727)	1	108	108
	2	107	107
	3	103	--
Narrow Body, 2 engine (DC-9/10/50, B737 DC-9-80, B757)	1	106	106
	2	106	106 (1)
	3	100.5	96

Note 1) Developed in "Cost/Benefit tradeoffs available in Aircraft Noise Technology Applications in the 1980s" for FAA, BBN Draft Report #3856, September 1978, Ref. 9 .

2) Estimated in relation to other aircraft of similar technology.

3. AIRPORT NOISE-AREA IMPACT MODEL

Testing the sensitivity of the Ref. 1 estimates of impacted area to changes in fleet mix, numbers of operations, and assumed noise requires a model that uses these parameters and that may be related to the areas calculated in Ref. 1 for the average busy runway airport cases. It is expected that a simplified noise-area impact model could be developed for each set of takeoff operational procedures. However, only procedure 1 (AC91-39 procedure) is considered in this study, because it is thought to be most representative of current practice.

The three cases used in development of the model are designated in Ref. 1:

- Year 1975 (Baseline). Aircraft, operations, and noise levels existing in 1975 with Flight Procedures 1 (departures per AC91-39 and arrivals per 1500 ft. intercept, 3 degree approach angle, and minimum flaps).
- Year 2000 (1,1,1). Flight Procedures 1, Technology 1 (Stages 2 and 3 and retrofit – replacement rule), and Fleet 1 (moderate growth scenario).
- Year 2000 (1,3A,1). Flight Procedures 1, Technology 3A (EPA's proposed 1985 rule – Stage 5), and Fleet 1.

The choice of these three cases essentially spans the L_{dn}-area data base for the busy runway airports.

Figure 3 illustrates an example of the relationship between the value of an L_{dn} contour and its enclosed area for the three cases. These three cases appear similar, but the year 2000 cases are displaced from the 1975 case by apparent noise reductions of 5 dB and 11.5 dB for the (1,1,1) and (1,3A,1) alternatives,

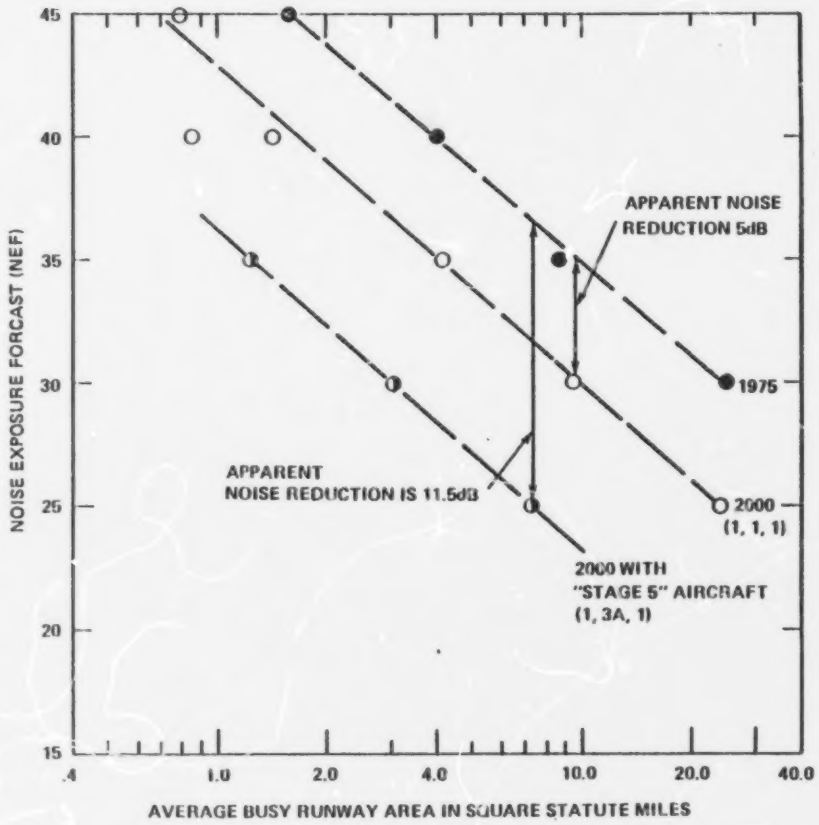

FIG. 3. RELATIONSHIPS BETWEEN L_{DN} CONTOUR VALUE AND AREA WITHIN CONTOUR FOR THE AVERAGE BUSY RUNWAY FOR AIRPORT CATEGORY A FOR THREE CASES: 1975 BASELINE, 2000 (1.1.1) AND 2000 (1,3A,1) FROM REF. 1.

respectively. Similar analyses for the other airport categories led to the definition of a total of eight values of apparent noise reduction.

These values were then compared to the noise reduction calculated for each of the airport categories and year, based on the L_{dn}* calculated at various fixed distances for two thrust conditions. The basic noise data from Ref. 1 for takeoff and maximum climb thrusts and at 1,000, 2,000, and 4,000 ft slant distances are given in Table 10. These data, together with the operations data, percent allocation by airport category, number of airports, and day/night correction to operations, etc., from Ref. 1 were used to compute L_{dn} values such as those in the "total" row in the example shown in Table 11.

Table 12 summarizes the apparent and calculated noise reductions. It is apparent that the noise reductions calculated using maximum climb thrust (MCT) EPNL at 1000 ft most closely approximate the apparent noise reductions in the Ref. 1 data. Therefore, the noise level at 1,000 ft (MCT) was selected as the basis for the noise-area impact model.

Figures 4, 5, 6, and 7 give for each of the four airport categories the relationship between the L_{dn} (1,000 ft) computed for MCT, the contour L_{dn}, and its associated busy runway area. For Categories A, B, and C-1, the data in Figs. 4, 5, and 6 are well represented by the straight line and its equation for areas larger than about 1 square mile. These equations are very similar and the reciprocal of the slope varies between 12.5 and 14. The data for Category C-2 shown in Fig. 7 has a steeper slope with a reciprocal of 18 for the data above about 0.6 square

*All L_{dn} values in Ref. 1 and in this report were calculated by adding 35 dB to the computed value of Noise Exposure Forecast (NEF).

TABLE 10 EFFECTIVE PERCEIVED NOISE LEVEL (EPNL) FROM YEAR 2000 STUDY AT VARIOUS DISTANCES (From Ref. 1).

AIRCRAFT	RULE	TAKEOFF THRUST (TOT)			MAX. CLIMB THRUST (MCT)		
		1000 Ft.	2000 Ft.	4000 Ft.	1000 Ft.	2000 Ft.	4000 Ft.
	Base	106	101	95	104	98	92
4 engine	1969	106	101	95	104	98	92
Wide Body	1975	105	100	94	103	97.5	91
	1985	95.5	89	83.5	94.5	87.5	81.5
	Base	102.5	95	88	101	93	86
2 & 3 engine	1969	102.5	95	88	101	93	86
Wide Body	1975	101	93.5	86	99.5	92	84
	1985	93	85	78	92	84	76.5
4 engine Narrow Body	Base	115	107	100	113	105	97
	Base	111	106	101	108	103	97.5
3 engine	1969	111	106	100	107	102	96.5
Narrow Body	1975	107	102	96.5	103	98	92.5
	1985	99.5	95	89	96	91	85
	Base	109	103	96	106	100	92.5
2 engine	1969	109	102.5	96	106	99	92.5
Narrow Body	1975	104	98	91	100.5	94	87
	1985	103	97	90	98.5	92	84.5

TABLE 11 EXAMPLE OF CALCULATION OF L_{dn} VALUES AT SEVERAL SLANT DISTANCES AND TWO THRUST CONDITIONS.

AVport Operations & Noise Worksheet: Year: 1975 Category: A

n = 13

A/C	RULE	National Annual Ops.	% of Nat'l Ops.	Annual Ops/ Category	Actual Daily Ops. Per Category	Actual Daily Ops. Per AVport	Effective Daily Takeoff Ops. AVport	Effective Daily Takeoff Ops. Busy Runway 0.3889	BUSY RUNWAY L_{dn} (dB) Takeoff Thrust (Tot) 600'	1000'	2000'	4000'	Max. Climb Thrust (MCT) 1000'	2000'	4000'	6000'
4 engine	Base	57,834		51,357	140.70	10.82	12.23	4.75	64.3	60.3	55.3	49.3	58.3	52.3	46.3	42.3
W. Body	1969	65,545		58,204	159.46	12.27	13.87	5.39	64.9	60.9	55.9	49.9	58.9	52.9	46.9	42.4
	1975		88.8													
2/3 engine	Base															
W. Body	1969	464,985		265,506	727.41	55.95	32.73	12.73	65.6	61.1	53.6	46.6	59.6	51.6	44.6	39.6
	1975		57.1													
4 engine	Base	1,065,635		599,953	1,643.71	126.44	204.83	79.66	85.6	81.6	73.6	66.6	79.6	71.6	63.6	59.1
N. Body	1969															
	1975		56.3													
3 engine	Base	2,335,472		745,016	2,041.14	157.01	164.70	64.05	80.1	76.6	71.6	66.6	73.6	68.6	63.1	59.6
N. Body	1969	890,092		283,939	777.92	59.84	62.77	24.41	75.9	72.4	67.4	62.4	69.4	64.4	58.9	54.4
	1975		31.9													
3 engine	Base															
N. Body	1969															
New Tech.	1975		31.9													
2 engine	Base	3,081,205		539,211	1,477.29	113.64	102.84	40.00	77.1	72.6	66.6	59.6	69.6	63.6	56.1	51.6
N. Body	1969	308,120		53,921	147.73	11.36	10.28	4.00	66.6	62.6	56.1	49.6	59.6	52.6	46.1	41.6
	1975		17.5													
TOTAL		8,268,888		2,597,107	7,115.36	547.33	604.25	234.99	87.5	83.6	76.9	70.8	81.3	74.4	67.5	63.4

TABLE 12. COMPARISONS OF NOISE LEVEL/SLANT DISTANCE/THRUST CANDIDATES FOR THEIR ABILITY TO PREDICT THE APPARENT NOISE REDUCTION FROM THE 1975 BASE CASE FOR ALL AIRPORT CATEGORIES AND FOR TWO FUTURE CASES: 2000(1,1,1) AND 2000(1,3A,1).

Airport Category	Case	Noise Reduction (dB) at Various Slant Distances						
		Apparent Noise Reduction (dB)	Takeoff Thrust			Maximum Climb Thrust		
			1000 Ft	2000 Ft	4000 Ft	1000 Ft	2000 Ft	4000 Ft
A	2000(1,1,1)	5.0	4.6	3.3	3.2	5.4	3.9	3.4
	2000(1,3A,1)	11.5	9.8	8.7	9.2	11.4	10.6	10.4
B	2000(1,1,1)	2.0	1.0	0.6	0.9	1.7	1.5	1.2
	2000(1,3A,1)	7.3	5.2	4.9	5.7	6.7	6.7	7.3
C-1	2000(1,1,1)	4.5	4.4	3.9	4.3	4.1	4.6	4.3
	2000(1,3A,1)	9.5	8.6	8.9	10.0	9.6	10.3	11.3
C-2	2000(1,1,1)	-1.0	-1.7	-1.4	-1.3	-1.4	-0.7	-1.0
	2000(1,3A,1)	3.0	1.2	1.3	1.7	2.5	3.1	3.6
Average difference between apparent and candidate noise reductions			-1.1	-1.46	-1.0	-0.2	-0.2	-0.2
Standard deviation of noise reduction differences			0.7	0.9	0.9	0.3	0.7	1.1
Error range			-2.1 to -0.1	-2.8 to -0.4	-2.3 to 0.5	-0.6 to 0.4	-1.1 to 0.8	-1.6 to 1.8

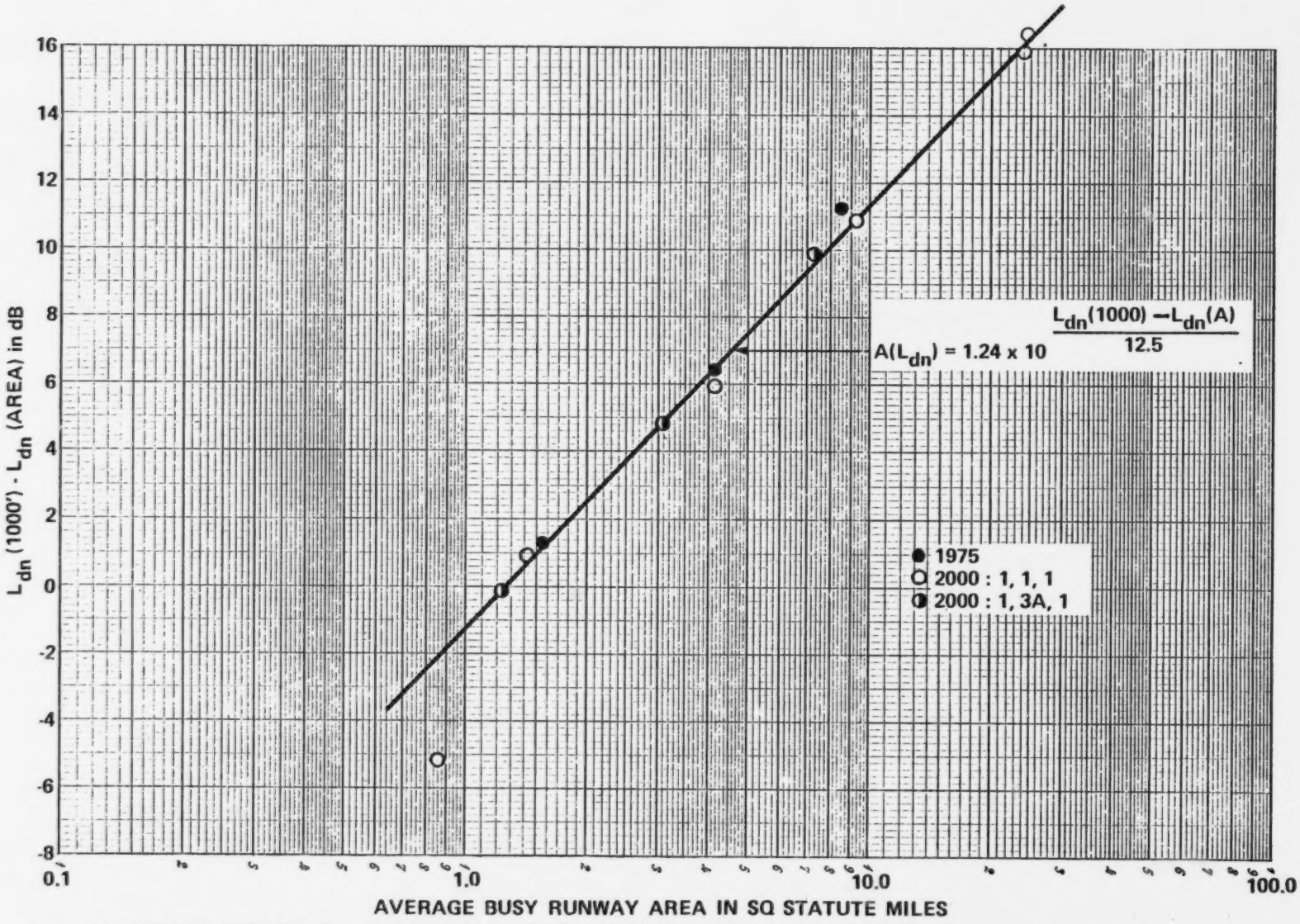

FIG. 4: AIRPORT CATEGORY A: BUSY RUNWAY AREA AS A FUNCTION OF THE L_{dn} AT 1000 FT SLANT DISTANCE FOR MAXIMUM CLIMB THRUST AND L_{dn} CONTOUR ASSOCIATED WITH EACH AREA FOR 3 CASES.

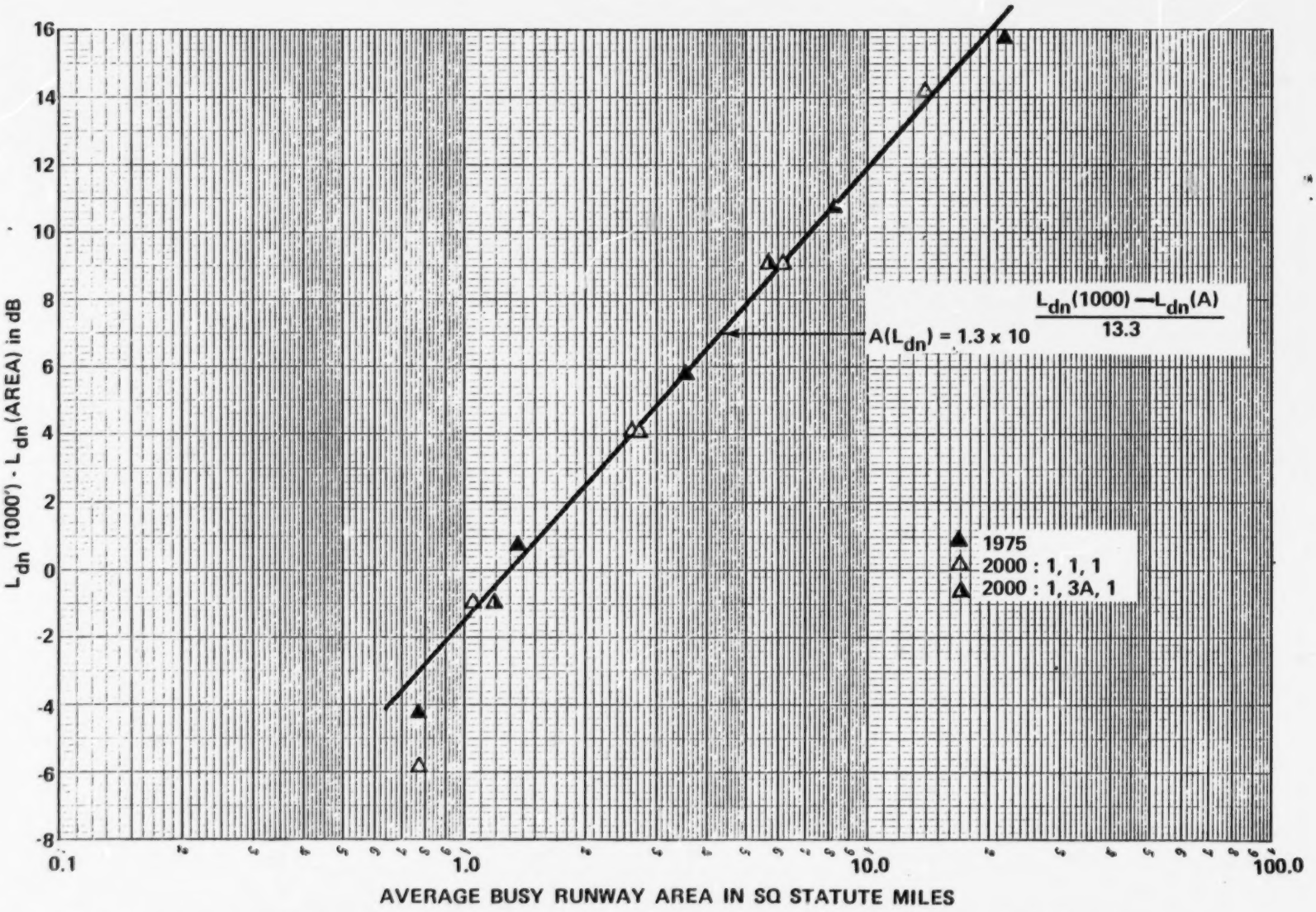

FIG. 5: AIRPORT CATEGORY B: BUSY RUNWAY AREA AS A FUNCTION OF THE L_{dn} AT 1000 FT SLANT DISTANCE FOR MAXIMUM CLIMB THRUST AND L_{dn} CONTOUR ASSOCIATED WITH EACH AREA FOR 3 CASES.

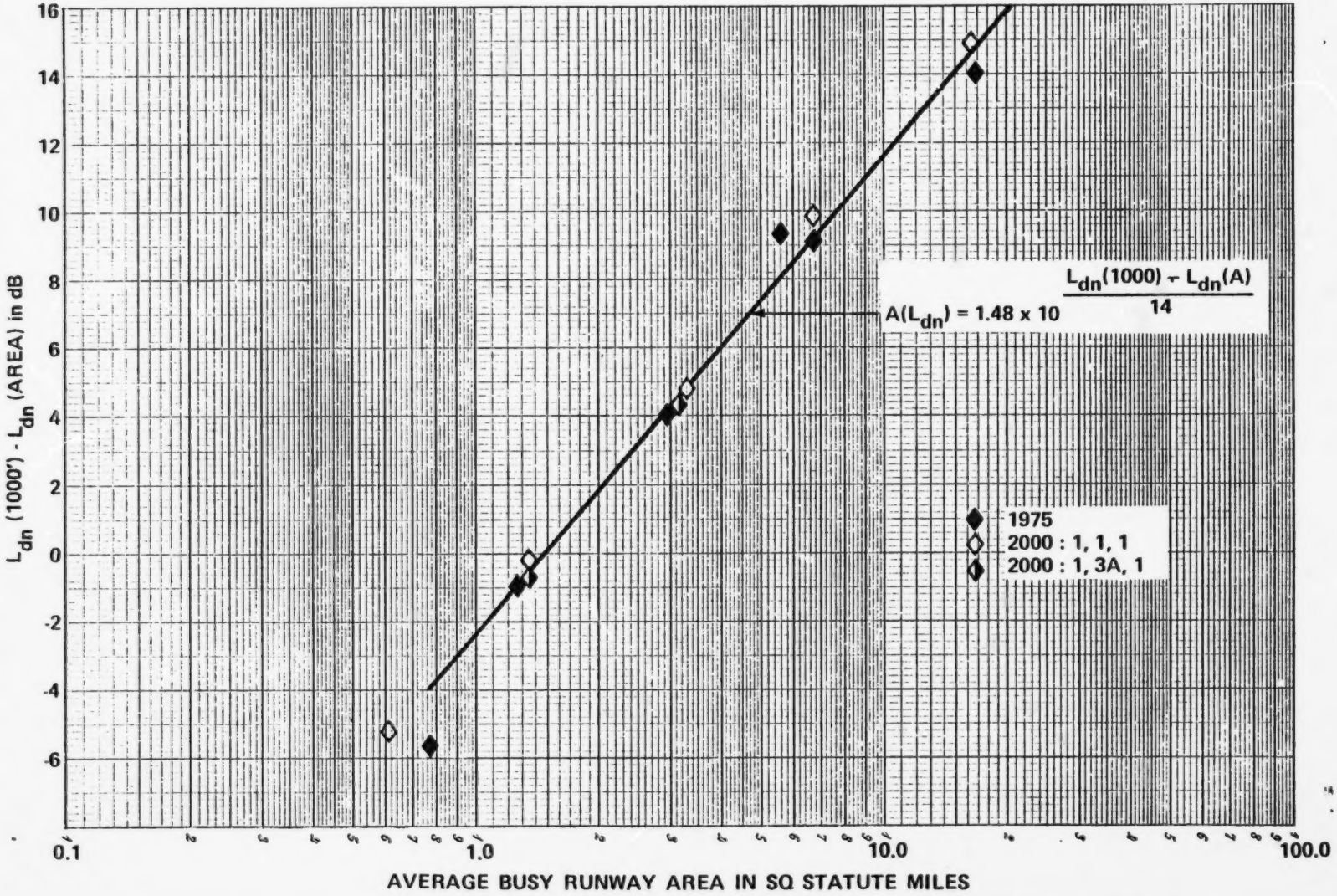

FIG. 6: AIRPORT CATEGORY C-1: BUSY RUNWAY AREA AS A FUNCTION OF THE L_{dn} AT 1000 FT SLANT DISTANCE FOR MAXIMUM CLIMB THRUST AND L_{dn} CONTOUR ASSOCIATED WITH EACH AREA FOR 3 CASES.

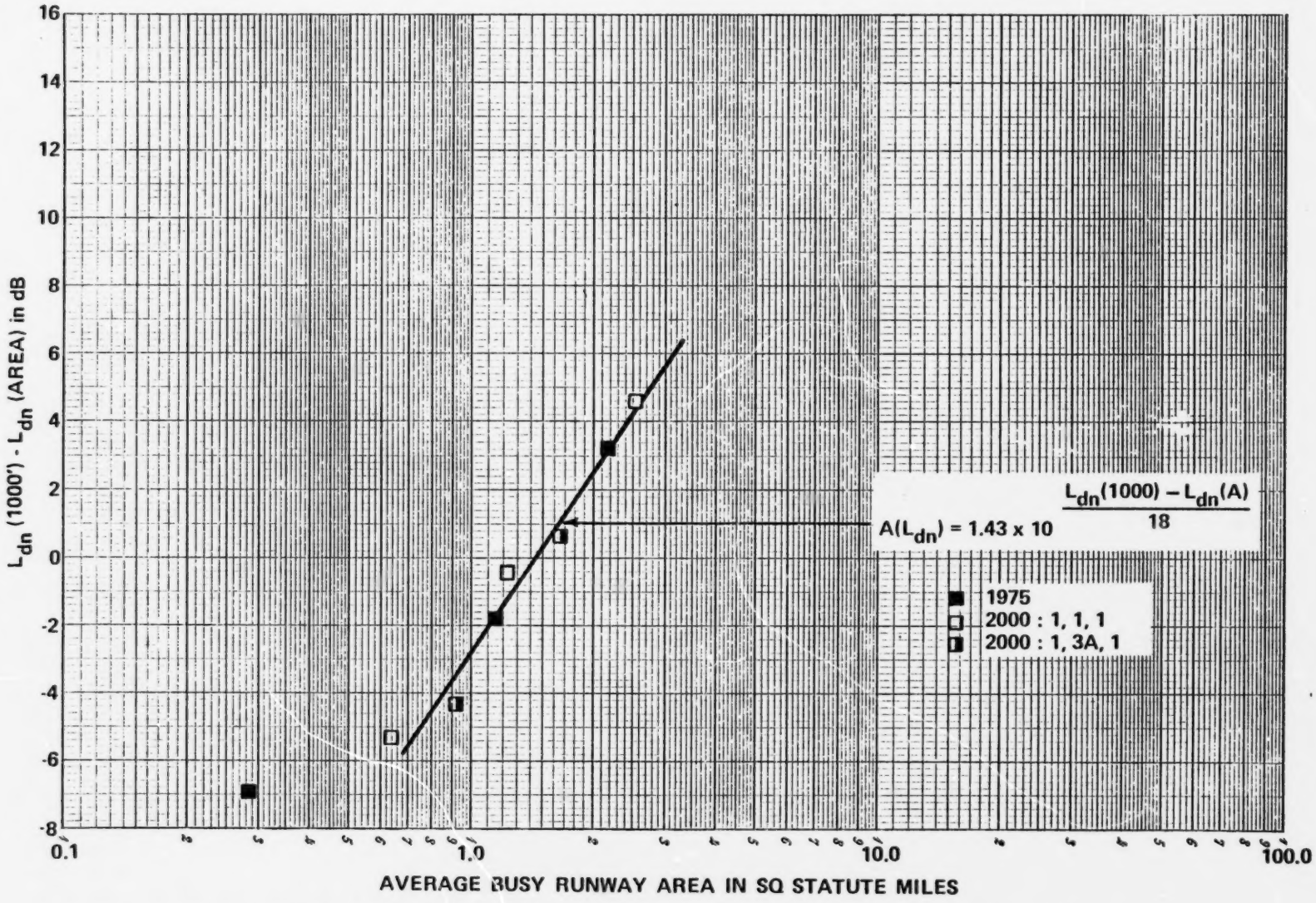

FIG. 7: AIRPORT CATEGORY C-2: BUSY RUNWAY AREA AS A FUNCTION OF THE L_{dn} AT 1000 FT SLANT DISTANCE FOR MAXIMUM CLIMB THRUST AND L_{dn} CONTOUR ASSOCIATED WITH EACH AREA FOR 3 CASES.

miles. It appears that the use of L_{dn} (1,000) MCT overstates the apparent noise reduction for this category of small airports with their small L_{dn} contours. A more approximate choice for this category would probably be L_{dn} (600 ft or 1,000 ft) for takeoff thrust with its characteristically lower values of noise reduction. (See Table 12.)

Figure 8 illustrates the collapse of all of these data points for all four airport categories. For areas larger than 1 square mile, almost all of the points are within 1 dB of the average relationship.

The noise area impact model developed above enables direct calculation of the average busy runway area within a specified contour value for each airport category from the L_{dn} calculated for MCT at 1,000 ft. This L_{dn} incorporates all of the operations data by aircraft type appropriate to an airport category and the aircraft noise data. The total areas for each category are obtained by multiplying the busy runway area by the scale factor for the appropriate category and year from Ref. 1. The total population for each category is obtained from the population-area relationships for the average airport in the category given in Fig. 2 and Table 3, and multiplying by the number of airports in the category.

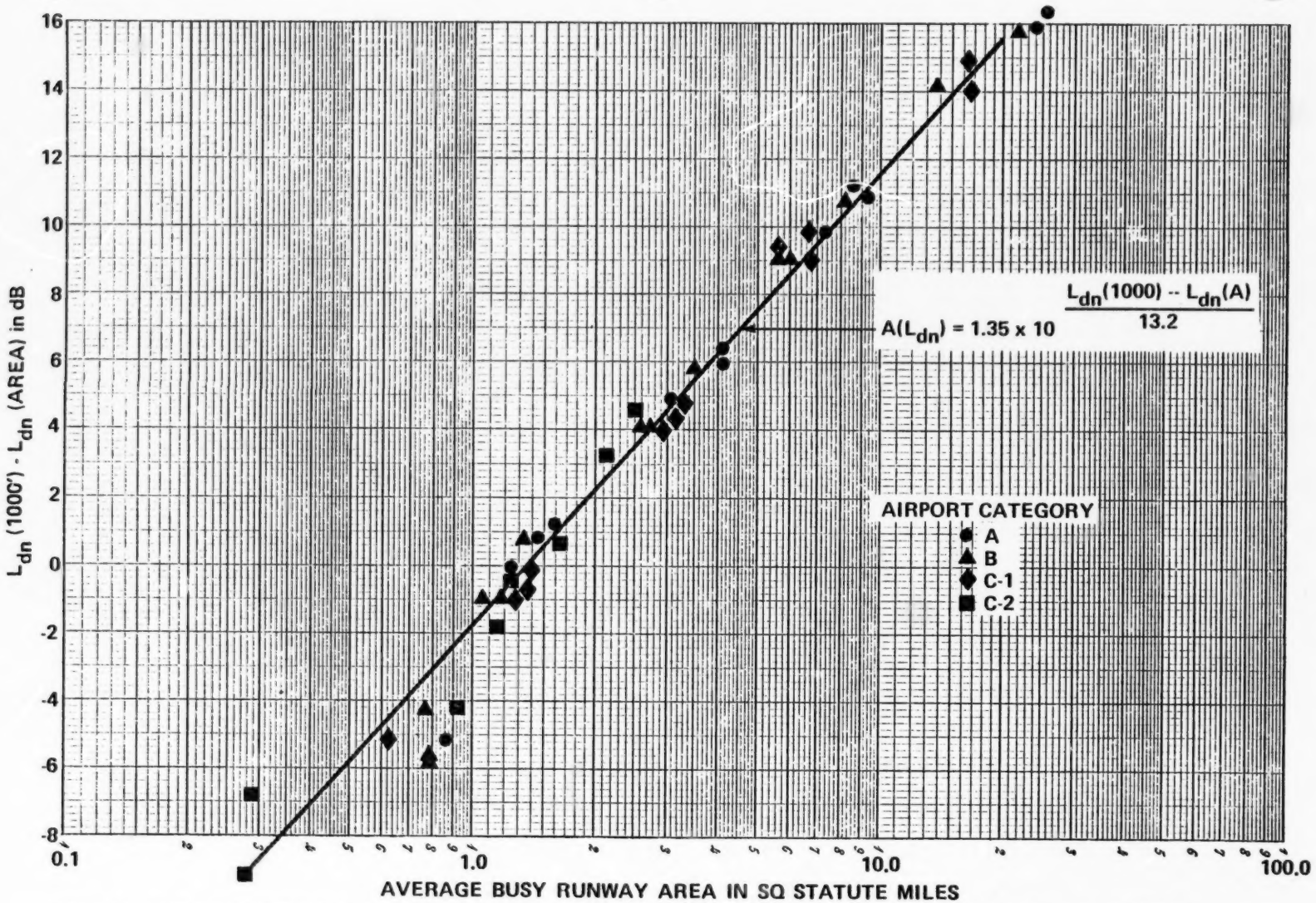

FIG. 8 COMBINATION OF ALL AIRPORT CATEGORIES: BUSY RUNWAY AREA AS A FUNCTION OF THE L_{dn} AT 1000 FT SLANT DISTANCE FOR MAXIMUM CLIMB THRUST AND L_{dn} CONTOUR ASSOCIATED WITH EACH AREA FOR 3 CASES.

4. SENSITIVITY ANALYSES

The updated information and model have been used to determine the sensitivity of both area and population results of Ref. 1 to the following variations and selected combinations:

- Refined definition of population in Category B
- Capacity limitation in Category C-1
- Updated fleet forecast
- Updated noise forecast.

The detailed results for the areas are summarized in Table 13a and given by category in Tables 13b-e for Airport Categories A through C-2. Similar results are given for population in Tables 14a-e.

(a) Refined Definition of Population in Category B, Case 2

This redefinition reduces the 1975 baseline population above L_{dn} 65 dB by 1,285,000, L_{dn} 70 dB by 306,000 and L_{dn} 75 dB by 9,000 people. The changes for the year 2000 are reductions of 879,000 and 171,000 people for L_{dn} 65 and 70 dB, respectively, and an increase of 12,000 people for L_{dn} 75 dB. These refined results (see Tables 14a and 14c), are considered to be more nearly correct than those of Ref. 1.

(b) Capacity Limitation for Airport Category C-1, Case 3

The capacity limit reduces the estimated area for the year 2000 by about 40% for Airport Category C-1. The total estimated population is reduced by a larger factor; from 587,000 to 187,000 within L_{dn} 65 dB, from 110,000 to 27,000 within L_{dn} 70 dB, and from 13,000 to 0 within L_{dn} 75 dB.

TABLE 13a. SUMMARY OF EFFECT OF CHANGES OF METHODS AND/OR ASSUMPTIONS ON THE *AREA*[1] FOR THE YEARS 1975 AND 2000. FOR THE AIRPORTS IN ALL CATEGORIES.

Changes in Method And/Or Assumption	L_{dn} > 65 dB			L_{dn} > 70 dB			L_{dn} > 75 dB		
	1975	2000		1975	2000		1975	2000	
	Sq. Miles		%[2]	Sq. Miles		%	Sq. Miles		%
1. Baseline without change	2169	1304	60	807	605	75	310	179	58
2. Refined definition of population in Category B	2169	1304	60	807	605	75	310	179	58
3. Capacity limitation in Category C-1	2169	1290	59	807	598	74	310	176	57
4. Combination of 2 and 3	2169	1290	59	807	598	74	310	176	57
5. Updated FAA fleet forecast	2169	1054	49	807	405	50	310	148	48
6. Combination of 4 and 5	2169	1047	48	807	402	50	310	147	47
7. Updated noise data	2169	997	46	807	377	47	310	133	43
8. Combination of 4 and 7	2169	985	45	807	371	46	310	131	42
9. Combination of all changes	2169	957	44	807	368	46	310	134	43
10. 9 but with all aircraft meeting Stage 3	2169	532	25	807	205	25	310	76	25

[1] Area is total contour area in square statute miles.

[2] Percent of 1975 values.

TABLE 13b. SUMMARY OF EFFECT OF CHANGES OF METHODS AND/OR ASSUMPTIONS ON THE *AREA*[1] FOR THE YEARS 1975 AND 2000. FOR THE AIRPORTS IN CATEGORY A.

Changes in Method And/Or Assumption	L_{dn} > 65 dB			L_{dn} > 70 dB			L_{dn} > 75 dB		
	1975	2000		1975	2000		1975	2000	
	Sq. Miles		%[2]	Sq. Miles		%	Sq. Miles		%
1. Baseline without change	746	269	36	256	120	47	122	41	34
2. Refined definition of population in Category B	746	269	36	256	120	47	122	41	34
3. Capacity limitation in Category C-1	746	269	36	256	120	47	122	41	34
4. Combination of 2 and 3	746	269	36	256	120	47	122	41	34
5. Updated FAA fleet forecast	746	262	34	256	100	39	122	40	33
6. Combination of 4 and 5	746	252	34	256	100	39	122	40	33
7. Updated noise data	746	217	29	256	86	34	122	34	28
8. Combination of 4 and 7	746	217	29	256	86	34	122	34	28
9. Combination of all changes	746	238	32	256	95	37	122	38	31
10. 9 but with all aircraft meeting Stage 5	746	159	21	256	63	25	122	25	20

[1] Area ia total contour area in square statute miles.

[2] Percent of 1975 values.

TABLE 13c. SUMMARY OF EFFECT OF CHANGES OF METHODS AND/OR ASSUMPTIONS ON THE *AREA*[1] FOR THE YEARS 1975 AND 2000. FOR THE AIRPORTS IN CATEGORY B.

Changes in Method And/Or Assumption	L_{dn} > 65 dB			L_{dn} > 70 dB			L_{dn} > 75 dB		
	1975	2000		1975	2000		1975	2000	
	Sq. Miles		%[2]	Sq. Miles		%	Sq. Miles		%
1. Baseline without change	1105	740	67	463	331	71	179	131	73
2. Refined definition of population in Category B	1105	740	67	463	331	71	179	131	73
3. Capacity limitation in Category C-1	1105	740	67	463	331	71	179	131	73
4. Combination of 2 and 3	1105	740	67	463	331	71	179	131	73
5. Updated FAA fleet forecast	1105	578	52	463	243	52	179	102	57
6. Combination of 4 and 5	1105	578	52	463	243	52	179	102	57
7. Updated noise data	1105	530	48	463	223	48	179	94	53
8. Combination of 4 and 7	1105	530	48	463	223	48	179	94	53
9. Combination of all changes	1105	521	47	463	219	47	179	92	51
10. 9 but with all aircraft meeting Stage 5	1105	275	25	463	116	25	179	49	27

[1] Area is total contour area in square statute miles.

[2] Percent of 1975 values.

TABLE 13d. SUMMARY OF EFFECT OF CHANGES OF METHODS AND/OR ASSUMPTIONS ON THE *AREA*[1] FOR THE YEARS 1975 AND 2000. FOR THE AIRPORTS IN CATEGORY C-1.

Changes in Method And/Or Assumption	L_{dn} > 65 dB			L_{dn} > 70 dB			L_{dn} > 75 dB		
	1975	2000		1975	2000		1975	2000	
	Sq. Miles		%[2]	Sq. Miles		%	Sq. Miles		%
1. Baseline without change	52	36	69	21	18	86	9	7	78
2. Refined definition of population in Category B	52	36	69	21	18	86	9	7	78
3. Capacity limitation in Category C-1	52	22	42	21	10	48	9	4	44
4. Combination of 2 and 3	52	22	42	21	10	48	9	4	44
5. Updated FAA fleet forecast	52	32	62	21	14	67	9	6	67
6. Combination of 4 and 5	52	25	48	21	11	52	9	5	56
7. Updated noise data	52	27	52	21	12	57	9	5	56
8. Combination of 4 and 7	52	15	29	21	6	29	9	3	33
9. Combination of all changes	52	23	44	21	10	48	9	4	44
10. 9 but with all aircraft meeting Stage 5	52	9	17	21	4	5	9	2	22

[1] Area is total contour area in square statute miles.

[2] Percent of 1975 values.

TABLE 13e. SUMMARY OF EFFECT OF CHANGES OF METHODS AND/OR ASSUMPTIONS ON THE *AREA*[1] FOR THE YEARS 1975 AND 2000. FOR THE AIRPORTS IN CATEGORY C-2.

Changes in Method And/Or Assumption	L_{dn} > 65 dB			L_{dn} > 70 dB			L_{dn} > 75 dB		
	1975	2000		1975	2000		1975	2000	
	Sq. Miles		%[2]	Sq. Miles		%	Sq. Miles		%
1. Baseline without change	266	259	97	67	137	204	0	0	0
2. Refined definition of population in Category B	266	259	97	67	137	204	0	0	0
3. Capacity limitation in Category C-1	266	259	97	67	137	204	0	0	0
4. Combination of 2 and 3	266	259	97	67	137	204	0	0	0
5. Updated FAA fleet forecast	266	192	72	67	48[3]	72	0	0[3]	0
6. Combination of 4 and 5	266	192	72	67	48	72	0	0	0
7. Updated noise data	266	223	84	67	56[3]	84	0	0[3]	0
8. Combination of 4 and 7	266	223	84	67	56	72	0	0	0
9. Combination of all changes	266	175	66	67	44[3]	66	0	0[3]	0
10. 9 but with all aircraft meeting Stage 5	266	89	67	22[3]	33	0	0[3]	0	0

[1]Area is total contour area in square statute miles.

[2]Percent of 1975 values.

[3]Area is smaller than lowest valid model area and is calculated by applying % of 1975 found for $L_{dn}65$ to the appropriate 1975 areas.

TABLE 14a. SUMMARY OF EFFECT OF CHANGES OF METHODS AND/OR ASSUMPTIONS ON THE *POPULATION*[1] FOR THE YEARS 1975 AND 2000 FOR THE AIRPORTS IN ALL CATEGORIES.

Changes in Method And/Or Assumption	L_{dn} > 65 dB			L_{dn} > 70 dB			L_{dn} > 75 dB		
	1975	2000		1975	2000		1975	2000	
	Population		%[2]	Population		%	Population		%
1. Baseline without change	6174	3581	58	1620	1033	64	393	125	32
2. Refined definition of population in Category B	4889	2699	55	1313	862	66	384	137	36
3. Capacity limitation in Category C-1	6174	3187	52	1620	943	58	393	112	28
4. Combination of 2 and 3	4889	2308	47	1313	765	58	384	124	32
5. Updated FAA fleet forecast	6174	2726	44	1620	610	38	393	71	18
6. Combination of 4 and 5	4889	1754	36	1313	516		384	84	22
7. Updated noise data	6174	2318	38	1620	494	31	393	52	13
8. Combination of 4 and 7	4889	1674	34	1313	411	31	384	65	17
9. Combination of all changes	4889	1742	35	1313	447	34	384	68	18
10. 9 but with all aircraft meeting Stage 5	4889	772	16	1313	150	11	389	15	4
11. Zero population density growth in Categories A and C-1 for 9	4804	1538	32	1290	405	31	376	64	17

[1]Population in thousands.

[2]Percent of 1975 values.

TABLE 14b. SUMMARY OF EFFECT OF CHANGES OF METHODS AND/OR ASSUMPTIONS ON THE *POPULATION*[1] FOR THE YEARS 1975 AND 2000 FOR THE AIRPORTS IN CATEGORY A.

Changes in Method And/Or Assumption	L_{dn} > 65 dB			L_{dn} > 70 dB			L_{dn} > 75 dB		
	1975	2000		1975	2000		1975	2000	
	Population		%[2]	Population		%	Population		%
1. Baseline without change	2105	763	36	593	255	43	215	17	8
2. Refined definition of population in Category B	2105	763	36	593	255	43	215	17	8
3. Capacity limitation in Category C-1	2105	763	36	593	255	43	215	17	8
4. Combination of 2 and 3	2105	763	36	593	255	43	215	17	8
5. Updated FAA fleet forecast	2105	713	34	593	184	31	215	15	7
6. Combination of 4 and 5	2105	713	34	593	184	31	215	15	7
7. Updated noise data	2105	673	32	593	143	24	215	28	4
8. Combination of 4 and 7	2105	673	32	593	143	24	215	28	4
9. Combination of all changes	2105	667	32	593	166	28	215	13	6
10. 9 but with all aircraft meeting Stage 5	2105	395	19	593	65	11	215	2	1
11. Zero population density growth in Categories A and C-1 for 9	2024	525	26	570	130	23	207	10	5

[1] Population in thousands.

[2] Percent of 1975 values.

TABLE 14c. SUMMARY OF EFFECT OF CHANGES OF METHODS AND/OR ASSUMPTIONS ON THE *POPULATION*[1] FOR THE YEARS 1975 AND 2000 FOR THE AIRPORTS IN CATEGORY B.

Changes in Method And/Or Assumption	L_{dn} > 65 dB			L_{dn} > 70 dB			L_{dn} > 75 dB		
	1975	2000		1975	2000		1975	2000	
	Population		%[2]	Population		%	Population		%
1. Baseline without change	2852	2115	74	887	629	71	159	95	60
2. Refined definition of population in Category B	1567	1236	79	581	458	79	150	107	71
3. Capacity limitation in Category C-1	2852	2115	74	887	629	71	159	95	60
4. Combination of 2 and 3	1567	1236	79	581	458	79	150	107	71
5. Updated FAA fleet forecast	2852	1505	53	887	359	40	159	52	33
6. Combination of 4 and 5	1567	733	47	581	295	51	150	67	45
7. Updated noise data	2852	1327	47	887	303	34	159	42	26
8. Combination of 4 and 7	1567	837	53	581	259	45	150	57	38
9. Combination of all changes	1567	820	52	581	252	43	150	54	36
10. 9 but with all aircraft meeting Stage 5	1567	353	23	581	85	15	150	13	9
11. Zero population density growth in Categories A and C-1 for 9	1567	820	52	581	252	43	150	54	36

[1]Population in thousands.

[2]Percent of 1975 values.

TABLE 14d. SUMMARY OF EFFECT OF CHANGES OF METHODS AND/OR ASSUMPTIONS ON THE *POPULATION*[1] FOR THE YEARS 1975 AND 2000 FOR THE AIRPORTS IN CATEGORY C-1..

Changes in Method And/Or Assumption	L_{dn} > 65 dB			L_{dn} > 70 dB			L_{dn} > 75 dB		
	1975	2000		1975	2000		1975	2000	
	Population		%[2]	Population		%	Population		%
1. Baseline without change	1118	587	53	136	110	81	19	13	68
2. Refined definition of population in Category B	1118	587	53	136	110	81	19	13	68
3. Capacity limitation in Category C-1	1118	187	17	136	27	20	19	0	0
4. Combination of 2 and 3	1118	187	17	136	27	20	19	0	0
5. Updated FAA fleet forecast	1118	442	40	136	65	48	19	4	21
6. Combination of 4 and 5	1118	242		136	35		19	2	11
7. Updated noise data	1118	230	21	136	45	33	19	2	11
8. Combination of 4 and 7	1118	76	7	136	8	6	19	0	0
9. Combination of all changes	1118	200	18	136	28	16	19	1	5
10. 9 but with all aircraft meeting Stage 5	1118	24	2	136	0	0	19	0	0
11. Zero population density growth in Categories A and C-1 for 9	1118	150	13	136	22	16	19	0	0

[1]Population in thousands.

[2]Percent of 1975 values.

TABLE 14e. SUMMARY OF EFFECT OF CHANGES OF METHODS AND/OR ASSUMPTIONS ON THE *POPULATION*[1] FOR THE YEARS 1975 AND 2000 FOR THE AIRPORTS IN CATEGORY C-2.

Changes in Method And/Or Assumption	L_{dn} > 65 dB			L_{dn} > 70 dB			L_{dn} > 75 dB		
	1975	2000		1975	2000		1975	2000	
	Population		%[2]	Population		%	Population		%
1. Baseline without change	99	116	117	4	32	800	0	0	0
2. Refined definition of population in Category B	99	116	117	4	32	800	0	0	0
3. Capacity limitation in Category C-1	99	116	117	4	32	800	0	0	0
4. Combination of 2 and 3	99	116	117	4	32	800	0	0	0
5. Updated FAA fleet forecast	99	66	67	4	2	50	0	0	0
6. Combination of 4 and 5	99	66	67	4	2	50	0	0	0
7. Updated noise data	99	88	89	4	3	75	0	0	0
8. Combination of 4 and 7	99	88	89	4	1	25	0	0	0
9. Combination of all changes	99	55	56	4	1	25	0	0	0
10. 9 but with all aircraft meeting Stage 5	99	15	15	4	0	0	0	0	0
11. Zero population density growth in Categories A and C-1 for 9	95	43	45	4	1	25	0	0	0

[1]Population in thousands.

[2]Percent of 1975 values.

(c) Updated Fleet Forecast, Case 5

The updated fleet forecast reduces the total area in 2000 by 17 to 33%, depending on the value of the L_{dn} contours. There is little change in Category A because the noise is dominated by the larger aircraft types which tended to have similar fleet forecasts for both years. The total estimated populations are reduced from 3,578,000 to 2,726,000 people for L_{dn} 65 dB, from 1,033,000 to 610,000 for L_{dn} 70, and from 125,000 to 71,000 for L_{dn} 75 dB.

(d) Updated Noise Data, Case 7

The application of updated noise data reduced the total area in 2000 by approximately 24 to 38% relative to the 2000 baseline of Ref. 1. The total populations were reduced by higher percentages, ranging from 35% to 58% to values of 2,318,000 within L_{dn} 65 dB, 494,000 within L_{dn} 70 dB, and 52,000 within L_{dn} 75 dB.

(e) Combination of Changes, Case 9

Tables 13 and 14 show the combination of the refined Category B population and the capacity constraint in Category C-1, together with each of the updated fleet forecasts. These combinations generally result in lower population for L_{dn} 65 and 70 dB but higher populations in L_{dn} 75 dB, because of the effect in Category B-1 previously discussed.

The table also gives the results for a combination of all changes. This combination is considered to be the most likely correct result in this study. The areas are reduced by 25% to 39% from the 2000 baseline of Ref. 1. The populations are

reduced by higher percentages, ranging between 46% and 57%, depending on L_{dn}. The resulting populations are 1,742,000 for L_{dn} 65 dB, which is 36% of the comparable 1975 value, 447,000 for L_{dn} 70 dB, which is 34% of the comparable 1975 value, and 68,000, which is 18% of the comparable 1975 value.

(f) Combination of Changes with all Aircraft Meeting Stage 5

If in 2000 all aircraft were to meet Stage 5 (Case 10), the values of land area are reduced by over 40% from the values estimated for 2000 with the combination of changes. The populations are similarly reduced to 772,000 in areas where the L_{dn} exceeds 65 dB. This case shows the maximum potential reduction in airport noise impact resulting from application of Stage 5 technology. However, it is a purely hypothetical case since by the time Stage 2 aircraft are phased out of the fleet, the fleet is expected to grow larger than the fleet estimates for 2000.

(g) Combination of Changes in Intermediate Years

Tables 15a - 15e present the estimated change in impact for the combination of changes (Case 9) at 5-year intervals between 1975 and 2000. The significant reduction in 1985 is the result of the retrofit program which eliminates the old 4-engine low by-pass narrow body aircraft from the fleet, and requires almost all remaining aircraft to meet Stage 2 requirements. There is then a pause in reduction of impact in 1990 followed by reductions in 1995 and 2000. This reduction trend would be expected to end once the Stage 2 aircraft are phased out, such that the fleet meets Stage 3 requirements. Subsequently, unless new aircraft meeting a more stringent "Stage 4" requirement account for future growth and replacement, noise impact will increase with the increase in operations.

(h) Combination of Changes by Airport Categories

The distribution of the population estimates for the combination of changes (Case 9) among the airport categories is summarized in Table 16. The most striking reduction is shown in Category C-1, as a result of the limit on capacity for growth, together with the introduction of quieter airplanes. Category A shows the next best improvement because of the elimination of the noisy narrow-body four-engine aircraft, the introduction of new quieter aircraft, and a less-than-average growth rate of operations that is the result of the Ref. 1 assumption in allocating aircraft types to airport categories. Categories B and C-2 show the least improvement because of their higher-than-average growth rate of operations and the continued dominance of the noise of narrow-body two- and three engine JT8D Stage 2 aircraft. The results for Category B would probably improve if the category were subdivided into three busy runway airports, each with its appropriate fleet mix corresponding to the subdivision made for calculation of population.

An additional calculation for L_{dn} 80 dB in 1975 indicates that the total is 66,000, almost identical to the total of 67,000 in 2000 living in areas above L_{dn} 75 dB. However, the allocation between Categories A and B are somewhat different, 22,000 to Category A and 44,000 to Category B, instead of the 13,000 and 54,000, respectively, shown for 2000.

TABLE 15a SUMMARY OF THE ESTIMATED AREAS[1] AND POPULATIONS EXPOSED TO LEVELS IN EXCESS OF VARIOUS DAY-NIGHT SOUND LEVELS AT 5 YEAR INTERVALS BETWEEN 1975 AND 2000 FOR ALL AIRPORT CATEGORIES.[2]

YEAR	L_{dn} > 65				L_{dn} > 70				L_{dn} > 75			
	Area		Population		Area		Population		Area		Population	
	Sq. Miles	%[3]	1000's	%[3]	Sq. Miles	%[3]	1000's	%[3]	Sq. Miles	%[3]	1000's	%[3]
1975	2169	100	4889	100	807	100	1313	100	310	100	384	100
1980	1895	87	4225	86	743	92	1240	94	275	89	303	79
1985	1344	62	2523	52	521	65	683	52	185	60	131	34
1990	1333	61	2562	52	518	64	711	54	186	60	136	35
1995	1166	54	2183	45	449	56	589	45	163	53	106	28
2000	957	44	1742	36	368	46	447	34	134	43	68	18

Notes: [1]Area is total contour area in square statute miles.

[2]Estimates include all changes (Case 9).

[3]Percent columns are percent of 1975 base.

TABLE 15b SUMMARY OF THE ESTIMATED AREAS[1] AND POPULATIONS EXPOSED TO LEVELS IN EXCESS OF VARIOUS DAY-NIGHT SOUND LEVELS AT 5 YEAR INTERVALS BETWEEN 1975 and 2000 FOR AIRPORT CATEGORY A.[2]

YEAR	L_{dn} > 65				L_{dn} > 70				L_{dn} > 75			
	Area		Population		Area		Population		Area		Population	
	Sq. Miles	%[3]	1000's	%[3]	Sq. Miles	%[3]	1000's	%[3]	Sq. Miles	%[3]	1000's	%[3]
1975	746	100	2105	100	256	100	593	100	122	100	215	100
1980	576	77	1547	73	229	89	540	91	91	75	130	60
1985	285	38	733	35	114	45	209	35	45	37	21	10
1990	297	40	799	38	118	46	233	39	47	39	25	12
1995	266	36	731	35	106	41	198	33	42	39	18	8
2000	238	32	667	32	95	37	166	28	38	31	13	6

Notes: [1] Area is total contour area in square statute miles.

[2] Estimates include all changes (case 9)

[3] Percent columns are percent of 1975 base.

TABLE 15c SUMMARY OF THE ESTIMATED AREAS[1] AND POPULATIONS EXPOSED TO LEVELS IN EXCESS OF VARIOUS DAY-NIGHT SOUND LEVELS AT 5 YEAR INTERVALS BETWEEN 1975 AND 2000 FOR AIRPORT CATEGORY B.[2]

YEAR	L_{dn} > 65				L_{dn} > 70				L_{dn} > 75			
	Area		Population		Area		Population		Area		Population	
	Sq. Miles	%[3]	1000's	%[3]	Sq. Miles	%[3]	1000's	%[3]	Sq. Miles	%[3]	1000's	%[3]
1975	1105	100	1567	100	463	100	581	100	179	100	150	100
1980	981	89	1433	91	413	91	522	90	174	97	149	99
1985	753	68	1132	72	317	72	387	67	133	74	99	66
1990	747	68	1170	75	315	75	401	69	132	74	102	68
1995	651	59	1034	66	274	66	340	59	115	64	82	55
2000	521	47	820	52	219	52	252	43	92	51	54	36

Notes: [1]Area is total contour area in square statute miles.

[2] Estimates include all changes (case 9)

[3] Percent columns are percent of 1975 base.

TABLE 15d SUMMARY OF THE ESTIMATED AREAS[1] AND POPULATIONS EXPOSED TO LEVELS IN EXCESS OF VARIOUS DAY-NIGHT SOUND LEVELS AT 5 YEAR INTERVALS BETWEEN 1975 AND 2000 FOR AIRPORT CATEGORY C-1.[2]

YEAR	L_{dn} > 65				L_{dn} > 70				L_{dn} > 75			
	Area		Population		Area		Population		Area		Population	
	Sq. Miles	%[3]	1000's	%[3]	Sq. Miles	%[3]	1000's	%[3]	Sq. Miles	%[3]	1000's	%[3]
1975	52	100	1118	100	21	100	136	100	9	100	19	100
1980	52	100	1128	101	23	110	172	126	10	111	24	126
1985	37	71	546	49	16	76	82	60	7	78	11	58
1990	34	65	488	44	15	71	73	54	7	78	9	47
1995	29	56	335	30	13	62	49	36	6	67	6	32
2000	20	38	200	18	9	43	28	21	4	44	1	5

Notes: [1]Area is total contour area in square statute miles.

[2]Estimates include all changes (case 9)

[3]Percent columns are percent of 1975 base.

TABLE 15e SUMMARY OF THE ESTIMATED AREAS[1] AND POPULATIONS EXPOSED TO LEVELS IN EXCESS OF VARIOUS DAY-NIGHT SOUND LEVELS AT 5 YEAR INTERVALS BETWEEN 1975 AND 2000 FOR AIRPORT CATEGORY C-2.[2]

YEAR	L_{dn} > 65				L_{dn} > 70				L_{dn} > 75			
	Area		Population		Area[3]		Population		Area[4]		Population	
	Sq. Miles	%[3]	1000's	%[3]	Sq. Miles	%[3]	1000's	%[3]	Sq. Miles	%[3]	1000's	%[3]
1975	266	100	99	100	67	100	4	100	0	0	0	0
1980	286	108	117	118	78	117	6	150	0	0	0	0
1985	269	101	111	112	74	111	5	125	0	0	0	0
1990	255	96	105	106	70	105	4	100	0	0	0	0
1995	220	83	83	84	56	83	2	50	0	0	0	0
2000	175	66	55	56	44	66	1	25	0	0	0	0

Notes: [1] Area is total contour area in square statute miles.

[2] Estimates include all changes (case 9)

[3] Percent columns are percent of 1975 base.

[4] See 3 on page 36.

TABLE 16. COMPARISON OF ESTIMATED POPULATION IN 1975 AND 2000 WITH THE COMBINATION OF ALL FOUR CHANGES[1] FOR EACH OF THE AIRPORT CATEGORIES AND FOR THREE VALUES FOR L_{dn}

AIRPORT CATEGORY	Population in 1000s								
	L_{dn} 65 dB			L_{dn} 70 dB			L_{dn} 75 dB		
	1975	2000		1975	2000		1975	2000	
	Population		%[2]	Population		%[2]	Population		%[2]
A (13 airports)	2105	667	32	593	166	28	215	13	6
B (113 airports)	1567	820	52	581	252	43	150	54	36
C-1 (2 airports)	1118	200	18	136	28	21	19	1	5
C-2 (179 airports)	99	55	56	4	1	35	0	0	0
Total (307 airports)	4889	1742	36	1313	447	34	384	68	18

Notes: [1]Combination of four changes in Case 9.

[2]Percent columns are % of 1975 values.

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APPENDIX A: FORECASTS OF AIR CARRIER OPERATIONS AT LAGUARDIA AND WASHINGTON NATIONAL AIRPORTS

The FAA's Terminal Area Forecast for 1980 to 1990 represents the latest official published forecast of airport operations for major U.S. airports. The figures are compiled initially by the Office of Aviation Policy, Aviation Forecast Branch using an unconstrained linear growth model, then are distributed to each FAA region for review and possible revision prior to publication.*

In the case of both LaGuardia and Washington National Airport, constraints on growth exist and have been applied by FAA's Eastern Region in its review of the normally unconstrained estimates. Growth at LaGuardia is constrained by the assumption that Newark and Stewart Airports will draw increasing numbers of operations from the New York area. At National, annual operations are constrained by regulation at 360,000 to control noise, and the air carrier share of the total is assumed to decrease to accommodate new air taxi service.*

Given these assumptions, the published 1980 and 1990 forecasts of air carrier operations at the two airports are given below. The 1985 forecast is an interpolation based on the linear growth model.

	1980	1985	1990
LGA	246,000	220,000	193,000
DCA	208,000	204,000	200,000

In the absence of further estimates, forecast operations beyond the year 1990 to the year 2000 are assumed (by BBN) to remain constant.

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*Ref. personal telephone conversation with AVP, 25 October 1979.